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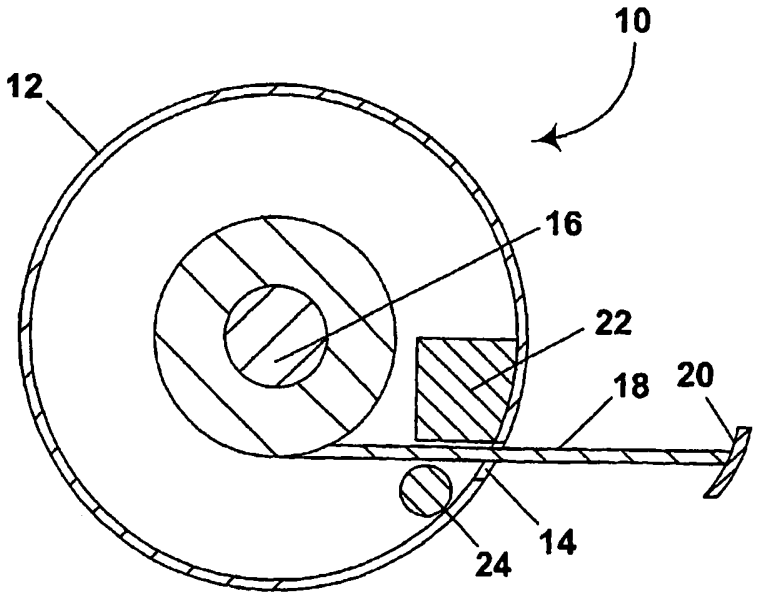

(57) Abstract: An apparatus (10) for displaying drawings comprises a housing (12) having an aperture (14), a drawing sheet (18) comprising electro-optic material movable through the aperture (14) between closed and open positions, and a writing device (22) for writing on the sheet (18) as it moved between its closed and open positions. The invention also provides a display comprising an optic medium capable of being changed between two display states, the display having a viewing surface through which an observer can view the medium. A touch screen is disposed on the opposed side of the optic medium from the viewing surface, and the optic medium is deformable such that pressure applied to the viewing surface will be transmitted to the touch screen.

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APPARATUS FOR DISPLAYING DRAWINGS

The present invention relates apparatus for displaying drawings. More specifically, this invention relates to an apparatus for displaying drawings which makes use of a rewritable medium, preferably an electrophoretic medium.

The present invention also relates to displays incorporating touch screens.

The term "drawings" is used herein to cover, *inter alia*, construction drawings, blueprints, architectural drawings, maps, plans, and similar types of technical drawings which may be required, for example, for the assembly, repair and maintenance of machinery.

Electro-optic displays comprise a layer of electro-optic material, a term which is used herein in its conventional meaning in the art to refer to a material having first and second display states differing in at least one optical property, the material being changed from its first to its second display state by application of an electric field to the material. The optical property is typically color perceptible to the human eye, but may be another optical property, such as optical transmission, reflectance, luminescence or, in the case of displays intended for machine reading, pseudo-color in the sense of a change in reflectance of electromagnetic wavelengths outside the visible range. The electro-optic material may be a particle-based electrophoretic material comprising at least one type of electrically charged particle capable of moving through a suspending fluid upon application of an electric field, and such an electrophoretic material may or may not be encapsulated; see, for example, U.S. Patents Nos. 5,930,026; 5,961,804; 6,017,584; 6,067,185; 6,118,426; 6,120,588; 6,120,839; 6,124,851; 6,130,773; 6,130,774; 6,172,798; 6,177,921; 6,232,950; 6,241,921; 6,249,271; 6,252,564; 6,262,706; 6,262,833; 6,300,932; 6,312,304; 6,312,971; 6,323,989; and 6,327,072; U.S. Patent Application Publication No. 2001-0045934; and International Applications Publication Nos. WO 97/04398; WO 98/03896; WO 98/19208; WO 98/41898; WO 98/41899; WO 99/10767; WO 99/10768; WO 99/10769; WO 99/47970; WO 99/53371; WO 99/53373; WO 99/56171; WO 99/59101; WO 99/67678; WO 00/03349; WO

00/03291; WO 00/05704; WO 00/20921; WO 00/20922; WO 00/20923; WO 00/26761; WO 00/36465; WO 00/36560; WO 00/36666; WO 00/38000; WO 00/38001; WO 00/59625; WO 00/60410; WO 00/67110; WO 00/67327 WO 01/02899; WO 01/07691; WO 01/08241; WO 01/08242; WO 01/17029; WO 01/17040; WO 01/17041; WO 01/80287 and WO 02/07216. All of these patents and published applications are in the name of, or assigned to, the Massachusetts Institute of Technology (MIT) or E Ink Corporation. Alternatively, the electro-optic material may be of the rotating bichromal member type as described, for example, in U.S. Patents Nos. 5,808,783; 5,777,782; 5,760,761; 6,054,071 6,055,091; 6,097,531; 6,128,124; 6,137,467; and 6,147,791 (although this type of display is often referred to as a "rotating bichromal ball" display, the tern "rotating bichromal member is preferred as more accurate since in some of the patents mentioned above the rotating members are not spherical). The electro-optic medium could also be an electrochromic medium, for example an electrochromic medium in the form of a nanochromic film comprising an electrode formed at least in part from a semi-conducting metal oxide and a plurality of dye molecules capable of reversible color change attached to the electrode; see, for example O'Regan, B., et al., Nature 1991, 353, 737. Nanochromic films of this type are also described, for example, in International Applications Publication Nos. WO 98/35267 and WO 01/27690. Other types of electro-optic materials, for example, liquid crystals, especially polymer-dispersed liquid crystals, may also be used in such displays.

Some electro-optic displays can have attributes of good brightness and contrast, wide viewing angles, state bistability, and low power consumption when compared with liquid crystal displays. (The terms "bistable" and "bistability" are used herein in their conventional meaning in the art to refer to displays comprising display elements having first and second display states differing in at least one optical property, and such that after any given element has been driven, by means of an addressing pulse of finite duration, to assume either its first or second display state, after the addressing pulse has terminated, that state will persist for at

least several times, for example at least four times, the minimum duration of the addressing pulse required to change the state of the display element.)

An encapsulated, electrophoretic display typically does not suffer from the clustering and settling failure mode of traditional electrophoretic devices and provides further advantages, such as the ability to print or coat the display on a wide variety of flexible and rigid substrates. (Use of the word "printing" is intended to include all forms of printing and coating, including, but without limitation: pre-metered coatings such as patch die coating, slot or extrusion coating, slide or cascade coating, curtain coating; roll coating such as knife over roll coating, forward and reverse roll coating; gravure coating; dip coating; spray coating; meniscus coating; spin coating; brush coating; air knife coating; silk screen printing processes; electrostatic printing processes; thermal printing processes; ink jet printing processes; and other similar techniques.) Thus, the resulting display can be flexible. Further, because the display medium can be printed (using a variety of methods), the display itself can be made inexpensively.

It has now been realized that the properties of many electro-optic media, and especially the aforementioned encapsulated electrophoretic media, in particular their rewritable nature and their bistability render such media especially adapted for solving certain problems associated with display of drawings under conditions often experienced in industry (including the construction industry). Accordingly, in one aspect this invention relates to apparatus useful for display of drawings and adapted to take advantage of the properties of such media.

Architects, builders and engineers employed in the construction industry working on large projects may require frequent access to hundreds, if not thousands, of drawings, and it is impracticable for them to carry a complete set of such drawings around with them. Although electronic storage of the necessary drawings would appear to be the solution, the display devices conventionally used with electronic storage are not well adapted for either the type of drawings involved or the environment in which they have to be used. Computer monitors based on cathode ray tubes are, of course, too large and heavy, and require too much power, to

be useful to someone moving around a construction site. Liquid crystal displays of the type used in portable computers are sufficiently light in weight and have sufficiently low power consumption for such purposes, but are fragile and difficult to read in sunlight. Furthermore, the maximum size of such displays is limited to about 15 inches diagonal, whereas construction drawings need to be much larger (typically about 24 by 36 inches) in order to show to scale details of a large building or device, and it is difficult to work with such drawings without seeing the whole drawing at once. Finally, construction sites present severe environmental hazards to portable computers, which may be damaged by rain, mud, blowing dust or excessive heat or cold. Similar problems are encountered by others needing access to large numbers of complex drawings, for example aircraft maintenance technicians.

The aforementioned media can readily be produced in the form of large, lightweight, tough rewritable sheets well adapted for display of construction and similar drawings, and such sheets can be incorporated into several types of storage devices which are less susceptible to the environmental hazards of construction sites and similar locations that are conventional portable computers. It is to such storage devices that the present invention relates.

In one aspect, this invention provides a first apparatus for displaying a drawing. This first apparatus comprises a housing having an aperture therein, and a drawing sheet movable through the aperture between a closed position, in which substantially the whole of the drawing sheet lies within the housing, and an open position in which at least a portion of the drawing sheet lies outside the housing. At least a portion of the drawing sheet comprises an electro-optic medium having first and second display states differing in at least one optical property, the medium being changed from its first to its second display state by application of an electric field to the medium. The apparatus also comprises writing means for writing on the electro-optic medium as the drawing sheet is moved from its closed to its open position and thereby producing a drawing on the electro-optic medium. This first apparatus of the invention may hereinafter be referred to as a "tube apparatus", since certain preferred embodiments of this apparatus, such as that illustrated in Figure 1 of the

accompanying drawings, have an external form which resembles a conventional mailing tube. It should be noted, however, that the housing of this first apparatus need not be tubular.

In another aspect, this invention provides a second apparatus for displaying a drawing. This second apparatus comprises a display member having a viewing surface, and support means for supporting the display member above a horizontal floor with the viewing surface facing upwardly. The second apparatus further comprises an electro-optic medium having first and second display states differing in at least one optical property, the medium being changed from its first to its second display state by application of an electric field to the medium, this electro-optic medium being disposed on the display member so as to be visible to an observer viewing the viewing surface. The second apparatus also comprises a writing head arranged to write on the electro-optic medium, and drive means for moving the writing head relative to the electro-optic medium. This second apparatus of the invention may hereinafter be referred to as a "table apparatus", since certain preferred embodiments of this apparatus, such as that illustrated in Figure 2 of the accompanying drawings, have an external form which resembles a table.

In another aspect, this invention provides a display comprising an optic medium having a viewing surface through which an observer can view the optic medium and on which the observer can press, the optic medium being changeable between first and second display states differing in at least one optical property on application of a stimulus thereto. The display further comprises a touch screen disposed on the opposed side of the optic medium from the viewing surface, the optic medium being deformable such that pressure applied to the viewing surface is transmitted to the touch screen.

Finally, this invention provides a process for writing on a protected layer of electro-optic material, this protected layer comprising a layer of electro-optic material and a protective envelope substantially completely surrounding the sheet of electro-optic material, the envelope having an openable and recloseable flap which can be opened to permit access to the layer of electro-optic material. This

process also uses a writing apparatus comprising at least two spaced retaining members and a writing head which can be moved between these spaced retaining members. The process comprises opening the flap of the envelope; inserting the spaced retaining members within the envelope, thereby creating a gap between the layer of electro-optic material and one internal surface of the envelope; moving the writing head between the spaced retaining members and thereby writing an image on the layer of electro-optic material; withdrawing the spaced retaining members from the envelope; and reclosing the flap of the envelope.

Figure 1 of the accompanying drawings is a schematic section through a first tube apparatus of the present invention, the section being taken in a plant perpendicular to the axis of the tube apparatus;

Figure 2 is a schematic section, similar to that of Figure 1, through a second tube apparatus of the present invention;

Figure 3 is a schematic vertical section through a table apparatus of the present invention;

Figure 4 is a schematic section through an apparatus of the present invention having a touch screen on the opposed side of an optic medium from a viewing surface; and

Figure 5 is a schematic top plan view of a writing apparatus carrying out the process of the present invention.

The accompanying drawings are not strictly to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

As already mentioned, in a first aspect this invention provides a "tube" apparatus for displaying a drawing, this apparatus comprising a housing having an aperture therein, and a drawing sheet movable through the aperture between an open and a closed position. An electro-optic medium having first and second display states differing in at least one optical characteristic is provided on the sheet, and the apparatus comprises writing means for writing on the electro-optic medium as the sheet is being moved from its closed to its open position.

This tube apparatus of the invention may have a rotatable spindle disposed within the housing, the drawing sheet, when in its closed position, being wound around the spindle, the drawing sheet being moved from its closed to its open position by being unwound from the spindle. In a preferred form of such a tube apparatus, the housing is substantially cylindrical, the spindle has an axis of rotation substantially parallel to the axis of the housing, and the aperture has the form of an elongate slot extending substantially parallel to the axis of the housing. The apparatus is conveniently provided with retraction means to retract the drawing sheet from its open to its closed position, and may also be provided with latching means having a latched position, in which the latching means prevent the retracting means retracting the drawing sheet from its open to its closed position, and an unlatched position, in which the latching means permits the retracting means to retract the drawing sheet from its open to its closed position. Conveniently, the writing means is mounted on the housing adjacent the aperture. The writing means may place upon the electro-optic medium an electrostatic charge which persists after the electro-optic medium has passed the writing means; this helps to retain the drawing on the electro-optic medium for the maximum time. The writing means may comprise a conductive member provided with biasing means arranged to bias the conductive member into contact with the drawing sheet as the writing means is writing on the drawing sheet, so that the conductive member forms one electrode of the writing means. Alternatively, at least the portion of the drawing sheet bearing the electro-optic medium may comprise a conductive layer to function as one electrode of the writing means.

In such a tube apparatus, a closure member may be secured to the drawing sheet in a position such that, when the drawing sheet is in its closed position, the closure member substantially closes the aperture, thus helping to prevent dust and dirt entering the housing when the drawing sheet is in its closed position. The apparatus may comprise data storage means for storing data representing a plurality of drawings, and data selection means for selecting at least

one of this plurality of drawings for writing by the writing means on to the display sheet.

When the tube apparatus is to be used in dirty or dusty environments, as will often be the case on construction sites, it will often be advantageous to provide a protective sheet covering the electro-optic medium. Since it may be difficult or impossible to write on the medium with the protective layer in place, the protective layer may be separable from the electro-optic medium and the writing means may comprise separating means for separating the protective layer from the electro-optic medium before the electro-optic medium is written by the writing means, the separating means permitting the protective layer to overlie the electro-optic medium after the electro-optic medium has been written by the writing means.

To enable a user to consult multiple drawings at the same time, the tube apparatus may comprise at least two discrete drawing sheets, each of the drawings sheets having an associated writing means so that different drawings can be displayed on each discrete drawing sheet. Such an apparatus may have a rotatable spindle provided within its housing, all the drawing sheets, when in their closed positions, being wound around this spindle. Alternatively, the apparatus may have a plurality of rotatable spindles disposed within the housing, one spindle being associated with each drawing sheet, each drawing sheet, when in its closed position, being wound around its associated spindle.

In the table apparatus of the invention having a display member and means for supporting this member above a horizontal floor, the display member may have the form of a hollow box, the electro-optic medium being disposed on an internal surface of this box, and the portion of this box adjacent the electro-optic medium being substantially transparent so as to enable an observer to see the electro-optic medium through the viewing surface, and the writing head may comprise an elongate member arranged to move within the box so as to write on the electro-optic medium. Alternatively, in such box-like table apparatus, the writing head may comprise a stylus member and the drive means may be arranged to move the writing head in two dimensions over the electro-optic medium. In another

embodiment of the table apparatus in which the display member has the form of a hollow box, the writing head may be disposed at a fixed location within the box, and the drive means may be arranged to drive the movable member past this fixed writing head.

Like the tube apparatus previously described, the table apparatus of the present invention may comprise data storage means for storing data representing a plurality of drawings, and data selection means for selecting at least one of this plurality of drawings for writing by the writing head on the electro-optic medium. The table apparatus may also comprise manually-operable data input means arranged so that data input to this data input means can modify a drawing displayed on the electro-optic medium. Data storage means may be operatively associated with the data input means and arranged to store modifications to drawings displayed on the apparatus and modified by data input to the data input means. The data input means may comprise one or more of a keyboard, a mouse, a joystick and a touch screen. In a preferred form of the table apparatus, the data input means comprises a touch screen disposed on the opposed side of the electro-optic medium from the viewing surface, the electro-optic medium being deformable such that pressure applied to the viewing surface is transmitted to the touch screen. In such an apparatus, the electro-optic medium is desirably substantially non-transmissive of visible light.

In both the tube and table apparatus of the present invention, the electro-optic medium may be of any of the types previously described, for example an electrochromic medium, a rotating bichromal member medium or an electrophoretic medium, especially an encapsulated electrophoretic medium.

As already mentioned, the present invention also provides a display comprising an optic medium having a viewing surface, and a touch screen disposed on the opposed side of the optic medium from the viewing surface. This type of display preferably uses an optic medium substantially non-transmissive of visible light. Either an air gap or a spacer layer may be provided between the optic medium and the touch screen. The optic medium may comprise a plurality of light emitting

diodes or an electro-optic medium, for example, an electro-chromic medium, a rotating bichromal member medium or an electrophoretic medium, especially an encapsulated electrophoretic medium.

As will readily be apparent to those skilled in the art of constructing displays, in such a display not only the optic medium itself but also electrodes and another other circuitry present adjacent the medium must withstand the deformation necessary to permit transmission of pressure from the viewing surface through the medium to the touch screen. Any of the known types of electrodes and associated circuitry may be used in the displays of the present invention. For example, the display may be of the "direct drive" type, in which one electrode is divided into a plurality of pixels and a discrete conductor and switching device are provided for each pixel; see for example the aforementioned WO 00/05704. Alternatively, the display may be of either the passive matrix or active matrix type, although it should be noted that certain types of optic media, because they lack a threshold, are not readily driven by a passive matrix technique. In an active matrix display a plurality of select lines and a plurality of data lines are provided, such that each pixel is defined uniquely by an intersection of a specific select line with a specific data line. Each pixel has a transistor, typically a thin film transistor, associated with it. One of the source and drain electrodes of the transistor is connected to a pixel electrode, which extends across the whole area of the pixel and applies an electric field to the optic medium (typically, in such an active matrix display, a single continuous electrode is used on the opposed side of the medium from the transistors). The other of the source and drain electrodes of the transistor is connected to a data line, while the gate of the transistor is connected to a select line (the data and select line connections could of course be reversed). See for example the aforementioned WO 00/67327. The use of organic semiconductors and/or organic conductive polymers may be useful in forming conductors and transistors with the necessary flexibility to withstand repeated deformations in the displays of the present invention.

In the process of the present invention, the layer of electro-optic material may be a discrete entity (i.e., a discrete sheet of electro-optic material), or

the layer may be disposed on one internal surface of the envelope, though the latter is generally preferred since it prevents the electro-optic material slipping, and perhaps bending or folding during the writing process. The layer of electro-optic material and the envelope may be substantially rectangular, the spaced retaining members may comprise two parallel elongate members, and the spaced elongate members be inserted into the envelope so as to extend substantially along an opposed pair of edges thereof, so that substantially the whole of the layer of electro-optic material is available for writing by the writing head. Conveniently, the spacing between the spaced containing members can be varied, so that the spaced retaining members can be inserted within the envelope and the spacing between the spaced retaining members thereafter increased, thereby placing the envelope under tension before the writing head writes the image. The writing head may be arranged to commence writing the image at a portion of the electro-optic medium remote from the flap and to write successive portions of the image closer to the flap. As in the tube and table apparatus previously described, the electro-optic medium may be an electro-chromic medium, a rotating bichromal member medium or an electrophoretic medium, especially an encapsulated electrophoretic medium.

A first preferred tube apparatus of the present invention, this tube apparatus being designed to resemble the cylinders conventionally used to transport and protect construction drawings, is illustrated in schematic cross-section in Figure 1 of the accompanying drawings. The apparatus (generally designated 10) comprises a substantially cylindrical housing 12, closed at both ends but with an elongate slot 14 running almost the full length of the housing 12 parallel to the axis thereof. A rotatable spindle 16 extends along the axis of the cylindrical housing 12, and a sheet 18 of electrophoretic medium is wound around the spindle 16. The sheet 18 is provided along one edge with a grip bar 20 which a user grips in order to pull the sheet 18 out of the housing 12, in the process unrolling the sheet 18 from around the spindle 16. The grip bar 20 is shaped so that when the sheet 18 is fully retracted within the housing 12, the grip bar 20 closes the slot 14, thus preventing dust or debris entering the housing 12. Thus, the sheet 18 can be moved manually between

a closed position, in which most of the sheet 18 is wound around the spindle 16 and only a small part of the sheet 18 extends from the spindle 16 to the grip bar 20 adjacent the slot 14 (so that the whole of the sheet 18 lies within the housing 12), and an open position, in which the major part of the sheet 20 lies outside the housing 12; Figure 1 illustrates the tube apparatus 10 as the sheet 18 is being moved from its closed to its open position.

As already indicated, the sheet 18 is intended to be pulled manually out of the housing 12. Obviously, it is necessary to provide a mechanism for retraction of the sheet 18 back into the housing 12, and this retraction mechanism may be of any convenient type. The retraction mechanism could be mechanical; for example, the spindle 16 could be provided with torsion springs which tighten as the sheet 18 is pulled from the housing 12, with a latching mechanism being provided to prevent premature retraction of the sheet 18 by the springs. Alternatively, the retraction mechanism could be power-operated; for example, a small electric motor could be provided to rotate the spindle 16 in order to retract the sheet 18. Obviously, if a power-operated retraction mechanism is provided, the same mechanism could also operate to drive the sheet 18 out of the housing 12.

Adjacent the slot 14 within the housing 12, there is provided a linear writing head 22 which writes an image on to the sheet 18 as the sheet is being pulled out of the housing 12. The writing head 22 may be of any of the types used for writing on electro-optic media, and thus may be, for example, in the form of a row of electrodes which contact the upper surface (in Figure 1) of the sheet 18, or in the form of a row of wires or corotrons which place electrostatic charge on the upper surface of the sheet 18 without physically contacting the sheet, although in general the latter is preferred. Whether the writing head 22 is of a contact or non-contact type, it is desirable that the writing head 22 and the sheet 18 be selected so that they operate together in the so-called "electrostatic" mode, in which the writing head 22 places upon the adjacent surface of the sheet 18 an electrostatic charge which persists upon this surface for an extended period of time. Operating in this electrostatic mode enables the sheet 18 to be imaged more quickly (since each

individual pixel of the image does not need to be in contact with the head 22 for the entire period necessary for the pixel to switch completely between its two optical states—each individual pixel can be in contact with the head 22 for a substantially shorter period, with the residual electrostatic charge left on the pixel sufficing to complete the switching process after the pixel has passed the head), and the persistence of the electrostatic charge on the medium increases the period for which the image remains stable.

A spring-biased roller 24 (a spring-biased bar could also be used) is provided adjacent the writing head 22 to bias the sheet 18 into proper contact with the writing head. At least the outer surface of the roller 24 is desirably electrically conductive so that the roller 24 can act as a counter electrode for the writing head 22. Alternatively, a conductive layer could be provided on the lower surface (in Figure 1) of the sheet 18 to act as such a counter electrode; for example, the sheet 18 could be formed from an aluminized polyester film, a material which is readily available commercially. In order to allow for variations in the speed with which the sheet 18 is manually withdrawn from the housing 12, at least a portion of the roller 24 is desirably provided with markings which can be detected by a photodetector (not shown) as the roller 24 rotates as the sheet 18 is withdrawn, the signals from the photodetector being used, in a known manner, to control the operation of the writing head 22.

As will readily be apparent to those skilled in the technology of electrophoretic and similar displays, the apparatus 10 should be provided with control circuitry for controlling the operation of the writing head 22, a battery for powering the control circuitry and the writing head, a data storage device capable of storing multiple images, and a selection device (for example, a rotary switch, conveniently provided on one end of the cylindrical housing 12) for selecting which of the stored images is to the printed on the sheet 18. The apparatus 10 is also desirably provided with a connector for interfacing with an external data storage and/or display device. For example, the apparatus 10 could be provided with a USB port to enable it to communicate with a computer, thus allowing for downloading of

images from a computer to the apparatus 10 and/or previewing on the computer of images stored in the apparatus 10. Alternatively or in addition, the apparatus 10 could be provided with a modem (desirably a wireless modem) to enable it to communicate with a central computer server on which a large number of images could be stored, thus enabling a user on site to receive any desired image from a company's collection.

The apparatus 10 can readily be constructed so that the sheet 18 can be replaced if it becomes excessively dirty or damaged in use. This is a substantial advantage, since electrophoretic media can be manufactured comparatively inexpensively, so that the sheet 18 could be replaced at a cost much lower than that of replacing the entire apparatus 10.

To reduce the need for replacement of the sheet of medium, the sheet may be provided with a protective cover, and a tube apparatus of this type (generally designated 10') is illustrated in Figure 2. The apparatus shown in Figure 2 closely resembles that shown in Figure 1 but uses a transparent protective sheet 30 that overlies and protects the sheet 18. Like the sheet 18, the protective sheet 30 is wound around the spindle 16 and has one edge attached to the grip bar 20. However, since it may be difficult or impossible to write on the sheet 18 with the protective sheet 30 overlying the sheet 18, the protective sheet 30 does not pass through the slot 14, but instead passes through an auxiliary slot 32 which is parallel to, but spaced from, the slot 14. Rollers 34 are provided to guide the protective sheet 30 through the slot 32.

The use of the protective sheet 30 may also be advantageous in reducing the tendency for images, written on electro-optic media using the electrostatic mode described above, to smear when users rub or slide their hands across the images. Although the exact mechanism of this smearing is not at present well understood, it is related to the removal by the users of the residual electrostatic charge remaining on the medium. Placing a protective sheet 30 over the imaged medium avoids direct contact between the user and the medium, thus essentially preventing removal of the residual electrostatic charge and the resultant smearing.